

SYSTEM FOR RECEIVING A CONTROL SIGNAL FROM A DEVICE FOR SELECTING ITS ASSOCIATED CLOCK SIGNAL FOR CONTROLLING THE TRANSFERRING OF INFORMATION VIA A BUFFER

This is a continuation of application Ser. No. 07/815,696, filed Dec. 30, 1991 now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to computer circuitry and, more particularly, to methods and apparatus for increasing the speed with which information is transferred between a source of data and a destination which is to use that data.

2. History of the Prior Art

A computer is typically constructed of a number of components which cooperate with each other to manage information. For example, a typical computer includes a central processing unit which includes circuitry for controlling the manipulation of data, a main memory in which data and instructions are typically stored during the operation of a computer program, a frame buffer in which data is stored for display, various input/output devices, and an output monitor. It is typical of most computer operations that information is constantly being transferred from one of these components to another during the operation of the computer by means of a bus which joins all of the devices.

Often the various individual components used with a computer system operate independently in carrying out operations in order to speed the overall operation of the computer system. In order to accomplish this, the individual components often have their own clocking arrangements to precisely time their internal operations. Examples of such components are those which include their own internal processors such as floating point processors and graphics accelerators. When information is transferred from one such component to another in prior art systems, the information which is synchronized to the clock of the sending component must be synchronized to the clock of the receiving component so that it can be correctly interpreted and used by the second component. To accomplish this, data is typically stored in word length increments in some form of memory at the source component and transferred a word at a time at the clock rate of the source component. At the interface between the source and the destination components, each word of information is synchronized with the clock of the destination component by an operation that typically requires two clock cycles. Once the information has been synchronized to the clock of the destination component, it is available for use by the destination component. Synchronization must take place each time information is transferred from a component which operates on one clock to a component which operates on another. Consequently, where the information is transferred between asynchronous components by a bus which operates at a different clock frequency than either the source or the destination component, two individual synchronization operations must take place.

As computers have become more capable, it has become desirable to transfer more information faster between components of the system. Moreover, it is just as desirable that the individual components operate at their own optimum internal clock rates so that each may carry out its functions most rapidly. The synchronization of information to the clock of the destination component and the storage of the information during transfer between components consumes

a substantial portion of the time required for the operation of a computer. It, therefore, becomes desirable to be able to provide some means for synchronizing the transfer of information between a large number of asynchronously operating components. The typical prior art computer has provided ad hoc synchronizing arrangements at each interface between two asynchronous devices. No simple arrangement for accomplishing synchronization between more than two components has yet been devised.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to accelerate the operation of computer systems.

It is another more specific object of the present invention to accelerate the transfer of information across computer interfaces.

It is yet another object of the present invention to accelerate the transfer of information across a computer interface by reducing the time required for the synchronization and storage of data.

It is still another object of the present invention to provide an arrangement for accelerating the transfer of information across a plurality of computer interfaces while reducing the time required for individual synchronization operations.

These and other objects of the present invention are realized in a computer system which comprises a first component having a first clock, means for storing information, means for transferring information from the first component to the means for storing information utilizing the clock of the first component, a second component having a second clock, and means for utilizing the clock of the second component to transfer information from the storage of the first component in a condition in which it is synchronized for use by the second component and may be immediately utilized by the second component without the need for storage by the second component.

These and other objects and features of the invention will be better understood by reference to the detailed description which follows taken together with the drawings in which like elements are referred to by like designations throughout the several views.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a typical computer system constructed in accordance with the prior art.

FIG. 2 is a block diagram of circuitry for synchronizing signals in accordance with the prior art.

FIG. 3 is a block diagram of circuitry in accordance with the invention for transferring information from one component of a computer system to another.

FIG. 4 is a block diagram of circuitry in accordance with the invention for transferring information from one component of a computer system to a plurality of other components.

NOTATION AND NOMENCLATURE

Some portions of the detailed descriptions which follow may be presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algorithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps

leading to a desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like. It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities.

Further, the manipulations performed are often referred to in terms, such as adding or comparing, which are commonly associated with mental operations performed by a human operator. No such capability of a human operator is necessary or desirable in most cases in any of the operations described herein which form part of the present invention; the operations are machine operations. In all cases the distinction between the method operations in operating a computer and the method of computation itself should be borne in mind. The present invention relates to apparatus for operating a computer in processing electrical or other (e.g. mechanical, chemical) physical signals to generate other desired physical signals.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 1 there is shown a block diagram of a prior art computer system 10. The system 10 includes a central processing unit 12, main memory 13, a frame buffer 15, a graphics accelerator 16, an output display device 17, and input/output circuitry 18. The central processing unit 12, the main memory 13, the graphics accelerator 16, the input/output circuitry 18, and the frame buffer 15 are joined to one another by a system bus 14.

Quite often in the design of a computer system, certain of the components will for one reason or another operate at different clock rates and will have different internal clock generators for providing the clock pulses used within the components. Typically, for example, a central processing unit 12 and a graphics accelerator 16 using an internal processor will each have its own clock. It is always necessary when transferring signals across an interface between two system components which operate at different clock frequencies that the incoming signals which are synchronized to the clock of the source component be synchronized to the clock of the destination component so that the information may be properly interpreted by the destination component.

Typically each word of information which is transferred between components is synchronized as it is transferred. This is a time consuming operation. This is usually accomplished by placing the word to be transferred in a register and simultaneously synchronizing a single bit of the word through a handshake line. The single bit is transferred on the handshake line while the remaining bits of the word are transferred on the data bus. Each handshake line (see FIG. 2) includes two stages of D flip-flops, each stage receiving the data bit at its D terminal and being enabled by the clock of the component receiving the particular signal. Whereas in a synchronous system, the input data and the clock are properly timed, this is not necessarily true in an asynchronous system. In general, a sufficient incoming signal will cause the first stage flip-flop 20 to switch while an insufficient signal will have no effect. However, an incoming

signal may cause the first stage flip-flop 20 to begin switching; and, because of the timing differential between the clock pulse of the destination component and the incoming signal, the first flip-flop 20 may assume a metastable condition, erratically switching between states until finally settling into either of the two possible states. If the incoming signal is of a sufficient amplitude that the first stage flip-flop 20 finally switches from this metastable condition, then the signal is transferred to the Q output terminal; and the incoming signals are synchronized with the clock of the destination component. If the input signal is insufficient and the first stage flip-flop 20 settles from the metastable condition into the wrong state, then the succeeding clock pulse will cause the first stage flip-flop 20 to transfer the signal; and the incoming signals and the clock of the destination component are synchronized. In either case, the final output of the first stage flip-flop 20 causes the second stage flip-flop 21 to take a state thereby isolating the dithering of the metastable state which may occur at the first stage flip-flop 20 from the destination circuitry. The state of the second stage flip-flop 21 is thus synchronized to the clock of the destination component. The remaining bits of the words carried on the data bus are clocked in as the second stage flip-flop is synchronized. This form of synchronization is commonly known as double rank synchronization.

It will be recognized that this form of synchronization is quite time consuming since it requires an average of two clock cycles and must be done for each word transferred between system components. However, this is the typical synchronization method used in prior art arrangements for accomplishing the transfer of data between asynchronous components.

It has now been found possible to eliminate a substantial amount of the time required to accomplish synchronization when transferring information between two asynchronous system components. The manner in which this is accomplished requires that information be transferred between system components in groups of words rather than as single words. In a preferred embodiment of the invention, information is transferred from the source component using the source clock and accumulated in a buffer holding up to sixty-four bytes of data before any information is transferred to the destination component. Other sizes of buffers would, of course, be possible. When a selected amount of information has accumulated and the transfer to the buffer is complete, a signal is sent to the destination component in synchronization with the clock of the source component. This signal is synchronized to the clock of the destination component in the typical fashion described above and requires the typical time to synchronize and transfer. However, the signal indicates to the destination component that the information has all been gathered in the buffer and that no operation is presently taking place with regard to that information. Since the receipt of the synchronization signal by the destination component indicates that the clock of the source component is not active with regard to the information in the buffer, it allows the clock of the destination component to be switched to the clock input terminals of the buffer which previously received the clock of the source component while storing the data.

The information is then transferred from the buffer of the source component for use by the destination component without any synchronization being necessary to the transfer. The information is simply clocked out by the clock of the destination component and is automatically synchronized to the destination component. Thus, the only synchronization necessary in the entire transfer is the synchronization of the

signal which indicates to the destination component that the data is ready in the buffer for transmission. No word by word synchronization of any sort is required. This substantially reduces the time required to transfer data between two components running on different clocks.

Not only does the transfer of information in this manner substantially reduce the synchronization time required, it also reduces the amount of system hardware and the number of steps necessary to move information. More particularly, if the information is stored using the clock of the source system component but moved out of the buffer in response to the clock of the destination system component, the buffer may be treated as a buffer of the destination component when the information is moved out. Because of this, the destination component need not store the information in a second internal buffer before it can be used. The information is immediately usable and may be used as it is clocked out of the buffer by the destination component. This has the effect of making the buffer first a part of the source component and then a part of the destination component and reducing the buffering circuitry by half. Thus, in addition to the time saved by using batch synchronization rather than per word synchronization, the time that would have been necessary to place the information in a second buffer and read it out for use is also saved.

Moreover, while prior art systems have required that ad hoc synchronization be accomplished at each individual interface, the present arrangement is especially adapted to allow the synchronization of a large number of asynchronous components. By storing information to be transferred in packets at a buffer of a source component and broadcasting a signal that the information is ready on a broadcast bus to a plurality of destination components, any of those destination components may synchronize to the broadcast signal and accept the information. This transfer of information is made easy and very rapid because any destination component need only furnish its clock to the source buffer and the information in the packet is automatically synchronized to the clock of the accepting destination. Thus, a very simple system is able to synchronize a plurality of asynchronous components.

FIG. 3 illustrates a basic circuit 22 for carrying out the invention of synchronizing the transfer of data between only two components. The circuit 22 includes a first component 23 and a second component 24. Each of the two system components operates in response to a different system clock. Consequently, data transferred between the two components 23 and 24 must be synchronized to the clock of the destination component 24 in order that the data be useful at the destination component.

In order to accomplish this result, a buffer 26 is provided. In FIG. 3, the buffer 26 is shown as a part of a circuit 25 (such as an integrated circuit) which includes the source component 23; the buffer 26 might also be positioned as a separate circuit component. The buffer 26 is arranged to receive information to be transferred from the component 23 to the component 24. The buffer 26 receives information transferred to it by the component 23 under control of the clock of the component 23. This clock is furnished to the buffer control circuitry by means of a multiplexor 27. In the preferred embodiment, such a buffer 26 is adapted to hold a maximum of sixty-four bytes of information.

When the buffer 26 has been filled with the information to be transferred, the component 23 generates a signal from a register 28 indicating that there is information ready to be transferred to the component 24. This signal is placed at the

D input terminal of a first synchronizing flip-flop 30 which is clocked as described above by the clock of the destination component 24. The output of the D flip-flop 30 is transferred to a second D flip-flop 32 which is also clocked by the clock of the destination component 24. The output of the second D flip-flop 32 is synchronized to the clock of the component 24 and thus may be read by the destination component 24 as indicating that there is information in the buffer 26 waiting to be transferred to the component 24. The signal also indicates that no information is being clocked into the buffer 26 by the component 23 and that the synchronization circuitry is not in use.

This being the case, a valid signal is transferred from the component 24 to operate the multiplexor 27 so that the clock of the component 24 is transferred by the multiplexor 27 to clock the information stored in the buffer 26 to the component 24 for use. At the same time, the D flip-flops 30 and 32 are furnished a clearing signal at a reset terminal by the component 24 so that they may be utilized for the next synchronization required for the transfer of information.

It will be realized by those skilled in the art that the information furnished from the buffer 26 is automatically synchronized to the clock of the component 24 without the necessity of synchronizing any individual word of the information through two flip-flop stages, let alone all of the words gathered in the buffer 26. This saves a substantial amount of time in the transfer of information. Moreover, the information clocked out of the buffer 26 is ready for use immediately by the component 24. Consequently, the buffer 26 which was initially a logical part of the component 23 has become, in effect, a buffer of the component 24, furnishing information to the elements of the component 24. This both saves the necessity of storing the information somewhere in the component 24 before it can be used and saves the time for so storing the information and retrieving it.

To transfer information from the second component 24 to the first component 23 requires that similar circuitry be utilized to provide buffering for the second component 24, to signal that information is ready to be transferred, and to switch the clock of the first component 23 to drive the transfer of information from the buffer of the second component 24. This might utilize some or all of the same circuitry as did the transfer from the component 23.

FIG. 4 illustrates an arrangement in accordance with the invention by which a block of information may be clocked into a buffer from a source of information as described above and later clocked out by one of a plurality of destination components. The circuit 40 includes a number of components 41-44, any of which may theoretically serve as a source of information or as a destination for information. Each of the components 41-44 is connected by a data path to a buffer 46 which may store a selected amount of information, an amount such as sixty-four bytes. This information is clocked into the buffer 46 under control of the clock of the particular component 41-44 which is the source of the data. The means for providing the clock from the source component is described below.

Associated with the buffer 46 is a launch or broadcast bus 47. Each of the components 41-44 is connected to the launch bus so that when it has completed the transfer of information to storage in the buffer 46, it may place an address on the launch bus 47 indicating that the transfer to the buffer 46 is complete and giving the address of the destination device. Each of the components 41-44 using a circuit 48 synchronizes the signal (at least one bit of the signal) placed on the launch bus 47 with its clock (the clock

of the addressed component). Each of the components 41-44 receives and decodes the address. When the addressed component is ready to receive the information, the addressed component returns a gate signal and its clock to a multiplexor 49 of the buffer 46. The multiplexor 49 transfers the clock from the addressed component to a counter 51 which controls the transfer of the information to the addressed component 41-44. In this manner, the information is written to the destination component under control of the destination clock and is immediately available for use by the destination component as in the arrangement shown in FIG. 3.

The multiplexor 49 illustrated in FIG. 4 is used in order to allow the clock of any one of the components to be used to clock the information into or out of the buffer 46. The multiplexor 49 includes an AND gate 52. The AND gate 52 receives input signals from all of the components 41-44. The input signals to the AND gate 52 are gated clock signals from each of the particular components. To accomplish this, an OR gate 54 is placed to receive the clock from the particular component 41-44 and a gate signal from that component. The gate signal indicates that the component is ready to send or receive information and is analogous to the valid signal sent from the source component in the circuit of FIG. 3. Normally when a component is not ready to transfer information, the gate signal is high. This high value is transferred by the OR gate 54 to the input of the AND gate 52. If none of the components are ready to send or receive information either because there is no information to send, none of the components are addressed, or the components are not ready if addressed, then a high value appears on each input to the AND gate 52. This high value is transferred to the counter. Consequently, no clock signal appearing at an OR gate 54 is transferred to the counter 51 to clock the information out of the buffer 46. On the other hand, when the gate signal at one of the OR gates 54 goes low, then the clock from the component 41-44 at that OR gate 54 is transferred to the AND gate 52. Since all of the other inputs to the AND gate 52 are high, the output of the AND gate 52 will reflect the high and low values of the clock from the selected destination component for transfer to the counter 51. In this manner, any of the components 41-44 may furnish its clock to the buffer 46 to clock information to the source component.

Thus, a plurality of asynchronous components may all be arranged with a simple and rapid synchronization system which allows any one of the components to receive the information from any other source component. The packetizing of information and the use of a broadcast bus to send signals from a source to which a plurality of destinations may synchronize, greatly enhances the speed of a computer system and makes possible the transfer of very large amounts of information.

Although the present invention has been described in terms of a preferred embodiment, it will be appreciated that various modifications and alterations might be made by those skilled in the art without departing from the spirit and scope of the invention. The invention should therefore be measured in terms of the claims which follow.

What is claimed is:

1. A computer system comprising a first component operated in response to timing of a first clock, means for storing information, means for transferring information from the first component to the means for storing information always utilizing the first clock without synchronization to another clock, a second component operated in response to timing of a second clock, the timing of the first clock being

independent of the timing of the second clock, means for utilizing the second clock to transfer information without synchronization with the first clock from the means for storing information without transferring other data into said means for storing information whereby the information may be immediately utilized by the second component without need for storage by the second component, said means for utilizing the second clock to transfer information without synchronization with the first clock from said means for storing information comprising means for transferring the information in said means for storing information to the second component under control of the second clock, said means for transferring the information in said means for storing information to the second component under control of the second clock includes means for switching the second clock to the terminals used by the first clock, said means for switching the second clock to the terminals used by the first clock includes a multiplexor, said multiplexor coupled to said first component and said second component, said multiplexor receiving a signal from the second component for furnishing a second clock signal from said second clock to said buffer to transfer data to said second component.

2. A computer system as claimed in claim 1 in which the means for utilizing the clock of the second component to transfer information from the storage of the first component in a condition in which it is synchronized for use by the second component comprises means for providing a signal to the second component to indicate that a prescribed amount of information has been stored in the buffer.

3. A computer system as claimed in claim 1, in which the means for switching the second clock to the terminals used by the first clock includes means for signaling the multiplexor that the second component is ready to accept the information in the buffer.

4. A computer comprising a plurality of components operated in response to timing of different clocks, means for storing information, means for utilizing the clock of any one of the components to transfer information without synchronization of timing of different clocks between one of the components and the means for storing information, means for signaling any of the components that information stored in the means for storing is to be transferred to that one of the components as a destination component, means for utilizing the clock of the destination component to transfer information from the means for storing information without synchronization of timing of different clocks in a condition in which the information is synchronized for use by the destination component wherein the means for utilizing the clock of any one of the components always utilizes the clock of the component transferring information into said means for storing information, and wherein the timing of the clock of the component from which the information was transferred is independent of the timing of the clock of the destination component, said means for utilizing the clock of the destination component to transfer information from the means for storing information in a condition in which it is synchronized for use by the destination component includes a multiplexor for transferring signals from addressed components to the means for storage, said multiplexor coupled to a first component and a second component, said multiplexor receiving a signal from said second component for furnishing a second clock signal from said second clock to said buffer to transfer data to said second component.

5. A computer as claimed in claim 4 in which the means for signalling another of the components that the information stored in the means for storing is to be transferred to the other of the components comprises means for synchronizing